National Aeronautics and Space Administration Goddard Earth Science Data Information and Services Center (GES DISC)

README Document for Suomi-NPP OMPS NMTO3-L3-DAILY Product

Version 2.1

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1.0 Introduction

This document provides basic information for using the Suomi National Polar-orbiting Partnership (NPP) Ozone Mapping and Profiling Suite (OMPS) Nadir Mapper (NM) Total Column Ozone (TO3) Level3 daily product, or OMPS-NPP_NMTO3-DAILY for short. OMPS-NPP_NMTO3-DAILY provides total column ozone retrievals determined from normalized radiance measurements taken by the NM sensor; The current version of this product provides aerosol index retrievals as well. Each file contains one orbit's worth of data.

1.1 OMPS Instrument Description

The Ozone Mapping and Profiling Suite (OMPS) is designed to measure the global distribution of total column ozone on a daily basis, as well as the vertical distribution of ozone in the stratosphere and lower mesosphere (~15-60 km). OMPS on the Suomi NPP satellite consists of three instruments:

Nadir Mapper (NM) – The Nadir Mapper measures total column ozone using backscattered UV radiation between 300-380 nm. A wide field-of-view telescope enables full daily global coverage using 50 km x 50 km pixels. Other quantities, such as aerosol index and column SO_2 abundance, can be derived from NM measurements.

Nadir Profiler (NP) – The Nadir Profiler measures stratospheric profile ozone with moderate vertical resolution (6-8 km) using backscattered UV radiation between 250-310 nm. The along-track footprint of NP is 250 km x 250 km.

Limb Profiler (LP) – The Limb Profiler measures limb scattered radiation in the UV, visible, and near-IR spectral regions to retrieve ozone density and aerosol extinction coefficient profiles from the lower stratosphere (10-15 km) to the upper stratosphere (55 km).

Only OMPS NMTO3 L2 retrievals and products will be described here.

1.1.1 Nadir Mapper

The OMPS nadir instrument is composed of two spectrometers that share the same telescope. A dichroic filter downstream of the telescope redirects photons into either the NM or the Nadir Profiler (NP) spectrometer. The telescope itself has a 110° total across-track field of view (FOV), resulting in 2800 km instantaneous coverage at the Earth's surface; this is sufficient to provide daily full global coverage at the equator for the NM sensor. The telescope includes a pseudo depolarizer [McClain et al., 1992] designed to minimize the system's sensitivity to incoming polarization. The dichroic filter is optimized to reflect most of the 250–310 nm light to the NP spectrometer and transmit most of the 300–380 nm light to the NM spectrometer.

Once split, the light from the NM spectrometer is dispersed via a diffraction grating onto one dimension of a two dimensional charge-coupled device (CCD) located at the spectrometer's focal plane. The second dimension reflects the cross-track spatial coverage provided by the slit aperture and optics. The CCD consists of 340 pixels along the spectral dimension and 740 pixels in the across-track spatial dimension.

Measurements meeting the 300–380 nm wavelength range specification required by the NM sensor are obtained by illuminating 196 of the 340 pixels in the spectral dimension. In the across-track dimension, 708 pixels are illuminated. For nominal operations, the pixel signals are summed into 35 separate "macropixel" FOVs; all but the two outer FOVs contain 20 pixels per macropixel; the left outermost macropixel contains 26 pixels, while the right outermost contains 22. Since the readout of the CCD is split in the center, measurements comprising the central FOV are actually split (although not symmetrically). Rather than rebinning these measurements in ground processing, they remain split, resulting in 36 cross-track FOVs. In this case, the central two FOVs comprise 12 pixels (30× 50km) and 8 pixels (20 × 50 km), respectively.

Because macropixels are constructed in programmable flight electronics, the OMPS nadir temporal (along-track) and spatial (across-track) resolutions are highly configurable. High-resolution measurements, approximately 10 km× 10 km at nadir, have been routinely collected 1 day per week for the first 2 years of the mission. To remain within the telemetry bandwidth constraints, a set of only 59 wavelengths was selected; this selection still allows retrievals of total column ozone and other quantities (such as SO_2).

1.2 Algorithm Background

NMTO3-L3-DAILY is based upon the TOMS Level 3 Gridded Software routine described in McPeters et al.

The level-3 gridding algorithm is used to combine the orbital OMPS cross track measurements into a daily map product with a fixed global grid. The adopted L3 grid is a 1.0-degree by 1.0-degree grid in longitude and latitude. The dimensions of the grid are 360 by 180. The center of the first grid cell is located at longitude -179.5 and latitude -89.5. The center of the final grid cell is located at longitude 179.5 and latitude 89.5. The center of the grid itself is located at longitude 0.0 and latitude 0.0, and corresponds to the corners of four grid cells.

At higher latitudes where orbital overlap occurs, only the average from the orbit that provides the best view of a given cell is reported. In practice, cell averages are computed separately for each orbit and the one with the shortest average path index is selected. The path index is calculated as $\sec(\theta_0) + 2\sec(\theta)$, where θ_0 and θ are the solar zenith and spacecraft zenith angles respectively, defined as the Instantaneous Field-of-View (IFOV). This index is designed to place more importance on the spacecraft zenith angle than on solar zenith angle relative to the proper calculation of geometric path ($\sec(\theta_0) + \sec(\theta)$).

The cell averages are computed as weighted averages of a given parameter derived for IFOVs that overlay the given cell. For this purpose, a simple rectangular model is used for the actual IFOV. The fractional area of overlap of the rectangular IFOV with a given ceil is used to weight its contribution to the given grid cell average. A single IFOV can contribute weight to more than one cell average within a single 1 degree latitude band. *Any* IFOV with its center outside the latitude band is ignored as a simplification to the calculation.

NMTO3-L3-DAILY is non-synoptic. On polar-orbiting satellites (such as Suomi-NPP, which has OMPS onboard), all measurements are made at a local time roughly equal to the Local Equator Crossing Time (LECT). The Western Pacific is measured near the beginning of the Greenwich Mean Time (GMT) day, and the Eastern Pacific is measured near the end of the GMT day. There is a 24- hour discontinuity in the data at 180th meridian. Individual IFOVs are sorted into different days across the 180th meridian to ensure that this is the only place where such a time discontinuity occurs. In order to accomplish this while providing a complete global map, some data from the previous GMT day are used at the beginning of our Level-3 day and some data from the next GMT day are used at the end. The LECT for each daily global file is provided in the output data.

1.2.1 Gridding Criteria

The L2 observation exclusion criteria are summarized here in sequence.

A1) As a rough first cut, L2 observations made outside of the 48-hour time interval centered at noon UTC day are excluded.

At any given moment, all points on Earth between the longitude of midnight and the dateline that are on the same side of the dateline have the same calendar date. The calendar dates on opposite sides of the dateline differ by one day, except at the instant when the longitude of midnight and the dateline coincide, in which case the date is the same everywhere on Earth.

A2) L2 observations with local calendar dates on the ground that correspond to the day before the L3 day are excluded.

A3) L2 observations with local calendar dates on the ground that correspond to the day after the L3 day are excluded.

A4) L2 observations with the solar eclipse possibility flag set are excluded.

After this point there are significant differences in how L2 observations are excluded from the L3 grids for the total column amount ozone and radiative cloud fraction, and 2) the L3 grid for the UV aerosol index.

Total Column Ozone and Radiative Cloud Fraction, and Reflectivity

There are two criteria in addition to A1 through A5 (above) for excluding L2 observations from the L3 grids for the total column amount ozone and radiative cloud fraction.

The L2 QualityFlags have the following values:

0 - good sample
1 - glint contamination (corrected)
2 - sza > 84 (degree)
3 - 360 residual > threshold
4 - residual at unused ozone wavelength > 4 sigma
5 - SOI > 4 sigma (SO2 present)
6 - non-convergence
7 - abs(residual) > 16.0 (fatal)
Add 8 for descending data.

B5) L2 observations gathered on the ascending part of the orbit that are not either a "good sample" or "glint contamination corrected" are excluded, as are all observations gathered on the descending part of the orbit.

B6) The path index is somewhat arbitrarily defined to be $1.0 / \cos(\theta_0)) + 2.0 / \cos(\theta)$, where θ and θ are the solar zenith and viewing zenith angles of the observation, respectively.

For any L3 grid cell that has a path index range exceeding 14.0, L2 observations that have a path index greater than or equal to the average value in the grid cell are excluded.

The implementation of this criterion, of course, requires two passes through the L2 observations. The first pass through calculates the path index range and average for all of the candidate L2 observations in each L3 grid cell.

With this information in hand, the second pass through then applies the criterion to exclude L2 observations from each L3 grid cell.

UV Aerosol Index

There are five criteria in addition to A1 through A5 (above) for excluding L2 observations from the L3 grid for the UV aerosol index.

C7) L2 observations gathered on the descending part of the orbit or with the "non-convergence" flag set are excluded.

C8) L2 observations with a solar zenith angle greater than or equal to 70.0 degrees are excluded.

C9) L2 observations with a path index greater than or equal to 7.0 are excluded.

C10) The glint angle is equal to the inverse cosine of

$$(\cos(\theta_0) * \cos(\theta) + \sin(\theta_0) * \sin(\theta) * \cos(\phi))$$

where ϕ is the relative azimuth angle of the observation. L2 observations with water at the ground pixel center and a glint angle less than or equal to than 20.0 degrees are excluded.

C11) L2 observations with a value of the UV aerosol index equal to the missing value (to within one part in a thousand) are excluded

C12) Values of the UV aerosol index less than 0.5 are excluded.

1.3 Data Disclaimer

Special high resolution diagnostic data were taken every Sunday from the beginning of the mission until 4 August 2013. Between 4 August 2013 and 25 June 2016, these data were taken every Saturday. Data for these days are not included as part of this V2.1.

1.4 What's New?

V2.1 is the first version of the dataset released through the GSFC DISC. The previous V1.0 dataset was available through NASA's OMPS science team's web site:

https://ozoneaq.gsfc.nasa.gov/omps

1.4.1 Version 2.1

V2.1 is the first version of the dataset released through the GES DISC. The previous V1.0 dataset was available through NASA's OMPS science team's web site:

https://ozoneaq.gsfc.nasa.gov/omps

Changes from V1.0 to V2.0 include:

Non science related changes

Nomenclature and Naming Convention

1) The naming convention for the L3 dataset has been changed from TC_EDR_TOC_DAILY to NMTO3-L3-DAILY
    a. TC (Total Column) has been replaced by NM (Nadir Mapper).
    b. NOAA nomenclature (EDR) has been replaced by NASA nomenclature (L3).
2) All capitalization of names within the file has been replaced by camel casing.
3) Underlines in all names have been eliminated.

Science related changes

The V2.1 dataset uses V2.1 of NMTO3-L2 as input.

2.0 Data Organization

2.1 File Naming Convention

The OMPS Nadir Mapper data products use the following file name convention:

OMPS-satellite_sensorproduct-**L**level_**v**m.n_observationDate_productionTime.**h5**

Where:

- satellite = NPP
- sensorproduct = NMTO3
- level = 3
- m.n = algorithm version identifier (m = major, n = minor)
- observationDate = start date of measurements in *yyyymmdd* format
    - *yyyy* = 4-digit year number[2012-current]
    - *mm* = 2-digit month number [01-12]
    - *dd* = 2-digit day number [01-31]
- productionTime = file creation stamp in *yyyy***m***mmdd***t***hhmmss* format
    - *hhmmss* = production time [local time]

Filename examples:

OMPS-NPP_NMTO3-L3-DAILY_v2.1_2017m0213_2017m0227t092659.h5

2.2 File Format and Structure

NMTO3-L3-DAILY data files are provided in the HDF5 format (Hierarchical Data Format Version 5), developed at the National Center for Supercomputing Applications http://www.hdfgroup.org/.

2.3 Key Science Data Fields

The data fields most likely to be used by typical users of the NMEV-L1B product are listed in this section. Important information about data temporal coverage and data quality is also provided.

Parameter
ColumnAmountOzone
RadiativeCloudFraction
Reflectivity331
UVAerosolIndex

2.3.1 Data Temporal Coverage

The first OMPS NMEV measurements used to create the NMEV-L1B product were taken on January 28, 2012. Data for February-March 2012 have numerous gaps due to variations in instrument. Regular operations began on April 2, 2012. Note that the OMPS Nadir Mapper conducted high-resolution measurements approximately one day per week from April 2012 to June 2016.

3.0 Data Contents

3.1 Global Attributes

Metadata in NMTO3-L3-DAILY data files includes attributes whose value is constant for all files and attributes whose value is unique to each individual file. Table 3.2.1 summarizes these global attributes.

Global Attribute	Type	Description
APPName	String	Software name
APPVersion	String	Software version
ArchiveSetName	String	Archive set name for processing
ArchiveSetNumber	Integer*8	Archive set number for processing
Conventions	String	Name of convention(s) for metadata
DOI	String	DOI value
DATA_QUALITY	Integer*4	Data quality flag
DayNightFlag	String	Identify day or night measurements
DayOfYear	String	Day of year for data
EastBoundingCoordinate	Real*4	Longitude bounding the data from the east
Format	String	Data file format
LocalGranuleID	String	File name
LongName	String	Full product name
NorthBoundingCoordinate	Real*4	Latitude bounding the data from the north
OrbitNumberStart	Integer*8	First orbit number of day
OrbitNumberStop	Integer*8	Last orbit number of day
PGEVersion	String	Software version (same as APPVersion)
ProductDateTime	String	Time of file creation
RangeBeginningDateTime	String	Starting date and time of data
RangeEndingDateTime	String	Ending date and time of data
ShortName	String	Short product name
SouthBoundingCoordinate	Real*4	Latitude bounding the data from the south
VersionID	Integer*4	Version ID for this product
VersionNumber	String	Version number for this product
WestBoundingCoordinate	Real*4	Longitude bounding the data from the west
acknowledgement	String	Acknowledgement of data producer
Comment	String	Any additional comments
contributor_name	String	Name of data creator
contributor_role	String	Role of data creator
creator_email	String	e-mail address of data creator
creator_institution	String	Organization of data creator
creator_name	String	Name of data creator
creator_type	String	Type of data creator (e.g. person, organization)
date_created	String	Date of file creation
geospatial_bounds_crs	String	The coordinate reference system (CRS) of the point coordinates in the geospatial_bounds attribute
geospatial_latitude_max	Real*4	Maximum latitude coordinate of the bounding box

geospatial_latitude_min	Real*4	Minimum latitude coordinate of the bounding box
geospatial_longitude_max	Real*4	Maximum longitude coordinate of the bounding box
geospatial_longitude_min	Real*4	Minimum longitude coordinate of the bounding box
history	String	History of file
id	String	Short product name
institution	String	Producer of data
instrument	String	Instrument making measurements
instrument_vocabulary	String	Source of instrument terms
keywords	String	Identifying keywords
keywords_vocabulary	String	Source of keywords used in metadata
license	String	Source of data information regulations
metadata link	String	Web address for metadata DOI
naming_authority	String	Organization providing naming information
platform	String	Platform for measuring instrument
processing_level	String	Level of data product (e.g. L1B, L2)
program	String	Type of measurement program
project	String	Name of project
publisher_email	String	e-mail address of data publisher
publisher_institution	String	Organization of data publisher
publisher_name	String	Name of data publisher
publisher_type	String	Organization type of data publisher
publisher_url	String	URL of data publisher
references	String	Reference material for data product
source	String	Source of measurement data
summary	String	Any additional summary
time_coverage_end	String	Ending data and time of data
time_coverage_start	String	Starting date and time of data
title	String	Title of data product

3.2 Products/Parameters

Dataset Name	Description	Units
ColumnAmountOzone	Total column ozone amount	DU
LandSeaMask	0 over water, 1 over land	(no units)
Latitude	Latitudes of the center for the pixels (-89.5 to 89.5)	degrees_north
Longitude	Longitudes of the centers for the pixels (-189.5 to 1809.5)	degrees_east
PercentWater	Percentage of pixel covered by water	%
RadiativeCloudFraction	Radiative cloud fraction	1 (unitless)
Reflectivity331	Reflectivity determined from the 331 nm wavelengths	1 (unitless)
SolarZenithAngle	Average solar zenith angle of the grid cell	degrees
UVAerosolIndex	UV aerosol index	(no units)
ViewingZenithAngle	Average viewing zenith angle of the grid cell	degrees

4.0 Options for Reading the Data

There are many tools and visualization packages (free and commercial) for viewing and dumping the contents of HDF5 files. Libraries are available in several programming languages for writing software to read HDF5 files. A few simple to use command-line and visualization tools, as well as programming languages for reading the L2 HDF5 data files are listed in the sections below. For a comprehensive list of HDF5 tools and software, please see the HDF Group's web page at https://www.hdfgroup.org/products/hdf5_tools/.

4.1 Command Line Utilities

4.1.1 h5dump (free)

The h5dump tool, developed by the HDFGroup, enables users to examine the contents of an HDF5 file and dump those contents, in human readable form, to an ASCII file, or alternatively to an XML file or binary output. It can display the contents of the entire HDF5 file or selected objects, which can be groups, datasets, a subset of a dataset, links, attributes, or datatypes. The h5dump tool is included as part of the HDF5 library, or separately as a stand-alone binary tool:

https://support.hdfgroup.org/HDF5/release/obtain5.html

4.1.2 ncdump (free)

The ncdump tool, developed by Unidata, will print the contents of a netCDF or compatible file to standard out as CDL text (ASCII) format. The tool may also be used as a simple browser, to display the dimension names and lengths; variable names, types, and shapes; attribute names and values; and optionally, the values of data for all variables or selected variables. To view HDF5 data files, version 4.1 or higher is required. The ncdump tool is included with the netCDF library. **NOTE: you must include HDF5 support during build.**

http://www.unidata.ucar.edu/downloads/netcdf/

4.1.3 H5_PARSE (IDL/commercial)

The H5_PARSE function recursively descends through an HDF5 file or group and creates an IDL structure containing object information and data values. You must purchase an IDL package, version 8 or higher, to read the L2 HDF5 data files.

http://www.harrisgeospatial.com/ProductsandTechnology/Software/IDL.aspx

4.2 Visualization Tools

4.2.1 HDFView (free)

HDFView, developed by the HDFGroup, is a Java-based graphic utility designed for viewing and editing the contents of HDF4 and HDF5 files. It allows users to browse through any HDF file, starting with a tree view of all top-level objects in an HDF file's hierarchy. HDFView allows a user to descend through the hierarchy and navigate among the file's data objects. Editing features allow a user to create, delete, and modify the value of HDF objects and attributes. For more info see:

https://support.hdfgroup.org/products/java/hdfview/

4.2.2 Panoply (free)

Panoply, developed at the Goddard Institute for Space Studies (GISS), is a cross-platform application which plots geo-gridded arrays from netCDF, HDF and GRIB dataset required. The tool allows one to slice and plot latitude-longitude, latitude-vertical, longitude-vertical, or time-latitude arrays from larger multidimensional variables, combine two arrays in one plot by differencing, summing or averaging, and change map projections. One may also access files remotely into the Panoply application.

https://www.giss.nasa.gov/tools/panoply/

4.2.3 H5_BROWSER (IDL/commercial)

The H5_BROWSER function presents a graphical user interface for viewing and reading HDF5 files. The browser provides a tree view of the HDF5 file or files, a data preview window, and an information window for the selected objects. The browser may be created as either a selection dialog with Open/Cancel buttons, or as a standalone browser that can import data to the IDL main program. You must purchase an IDL package, version 8 or higher to view the L2 HDF5 data files.

http://www.harrisgeospatial.com/ProductsandTechnology/Software/IDL.aspx

4.3 Programming Languages

Advanced users may wish to write their own software to read HDF5 data files. The following is a list of available HDF5 programming languages:

Free:

C/C++, Fortran (https://support.hdfgroup.org/HDF5/)

Java (https://support.hdfgroup.org/products/java/release/download.html)

Python (http://www.h5py.org/)

GrADS (http://cola.gmu.edu/grads/)

Commercial:

IDL (http://www.harrisgeospatial.com/ProductsandTechnology/Software/IDL.aspx)

Matlab (https://www.mathworks.com/products/matlab/)

5.0 Data Services

Access of GES DISC data now requires users to register with the NASA Earthdata Login system and to request authorization to "NASA GESDISC DATA ARCHIVE Data Access". Please note that the data are free of charge to the public.

5.1 GES DISC Search

The GES DISC provides a keyword, spatial, temporal and advanced (event) searches through its unified search and download interface:

https://disc.gsfc.nasa.gov/

The interface offers various download and subsetting options that suit the user's needs with different preferences and different levels of technical skills. Users can start from any point where they may know little about a particular set of data, its location, size, format, etc., and quickly find what they need by just providing relevant keywords, such as a data product (e.g. "OMPS"), or a parameter such as "ozone".

5.2 Direct Download

The OMPS data products may be downloaded in their native file format directly from the archive using https access at:

https://snpp-omps.gesdisc.eosdis.nasa.gov/data/

5.3 OPeNDAP

The Open Source Project for a Network Data Access Protocol (OPeNDAP) provides remote access to individual variables within datasets in a form usable by many OPeNDAP enabled tools, such as Panoply, IDL, Matlab, GrADS, IDV, McIDAS-V, and Ferret. Data may be subsetted dimensionally and downloaded in a netCDF4, ASCII or binary (DAP) format. The GES DISC offers the OMPS data products through OPeNDAP:

https://snpp-omps.gesdisc.eosdis.nasa.gov/opendap/

6.0 More Information

Contact Information

Name: GES DISC Help Desk
URL: https://disc.gsfc.nasa.gov
E-mail: gsfc-help-disc@lists.nasa.gov
Phone: 301-614-5224
Fax: 301-614-5228
Address: Goddard Earth Sciences Data and Information Services Center
Attn: Help Desk
Code 610.2
NASA Goddard Space Flight Center
Greenbelt, MD 20771 USA

Additional OMPS and ozone data products

https://ozoneaq.gsfc.nasa.gov/

Suomi-NPP mission web page

https://jointmission.gsfc.nasa.gov/suomi.html

7.0 Acknowledgements

These data should be acknowledged by citing the product in publication reference sections as follows:

Richard D. McPeters, "OMPS-NPP L3 NM Ozone (O3) Total Column 1.0 deg grid daily V2", Greenbelt, MD, USA, Goddard Earth Sciences Data and Information Services Center (GES DISC), accessed ***[data access date]***, doi:10.5067/Y7YKSA1QNQP8

References

Richard D. Mcpeters, P.K. Bhartia, Arlin J. Krueger, and Jay R. Herman, "Total Ozone Mapping Spectrometer (TOMS) Level-3 Data Products User's Guide", NASA/TP-2000-209296.